MINIMUM STANDARD 3.13

GRASSED SWALE

View BMP Images

LIST OF ILLUSTRATIONS

MINIMUM STANDARD 3.13

GRASSED SWALE

Definition

A grassed swale is a broad and shallow earthen channel vegetated with erosion resistant and flood-tolerant grasses. Check dams are strategically placed in the swale to encourage ponding behind them.

A water quality swale is a broad and shallow earthen channel vegetated with erosion resistant and flood tolerant grasses, and underlain by an engineered soil mixture.

Purpose

The purpose of grassed swales and water quality swales is to convey stormwater runoff at a non-erosive velocity in order to enhance its water quality through infiltration, sedimentation, and filtration. Check dams are used within the swale to slow the flow rate and create small, temporary ponding areas. A water quality swale is appropriate where greater pollutant removal efficiency is desired.

Water Quality Enhancement

Grassed swalesand water quality swales remove pollution through *sedimentation*, *infiltration*, and *filtration*. Water quality swales are specifically engineered to filter stormwater through an underlying soil mixture while grasses swales are designed to slow the velocity of flow to encourage settling and filtering through the grass lining. Vegetation filters out the sediments and other particulate pollutants from the runoff and increases the opportunity for infiltration and adsorption of soluble pollutants. The flow rate becomes a critical design element, since runoff must pass through the vegetation slowly for pollutant removal to occur. Monitoring of grassed swales has indicated low to moderate removal of soluble pollutants (phosphorous and nitrogen) and moderate to high removal of particulate pollutants.

Flood Control

Grassed swales and water quality swales will usually provide some peak attenuation depending on the storage volume created by the check dams. However, flood control should be considered a secondary function of grassed swales since the required storage volume for flood control is usually more than they can provide.

FIGURE 3.13 - 1
Typical Grassed Swale Configuration

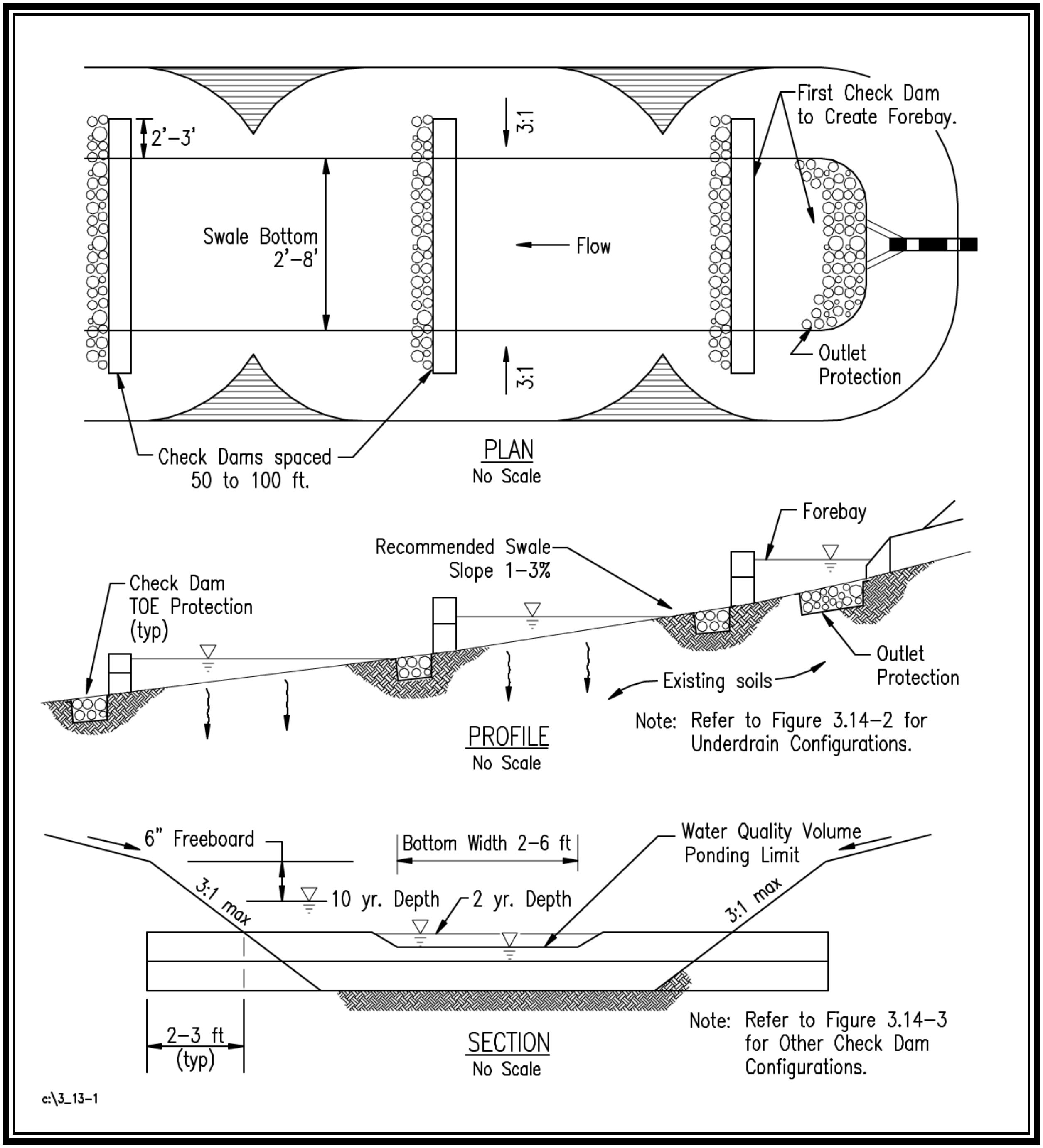


FIGURE 3.13 - 2
Typical Water Quality Swale Configuration

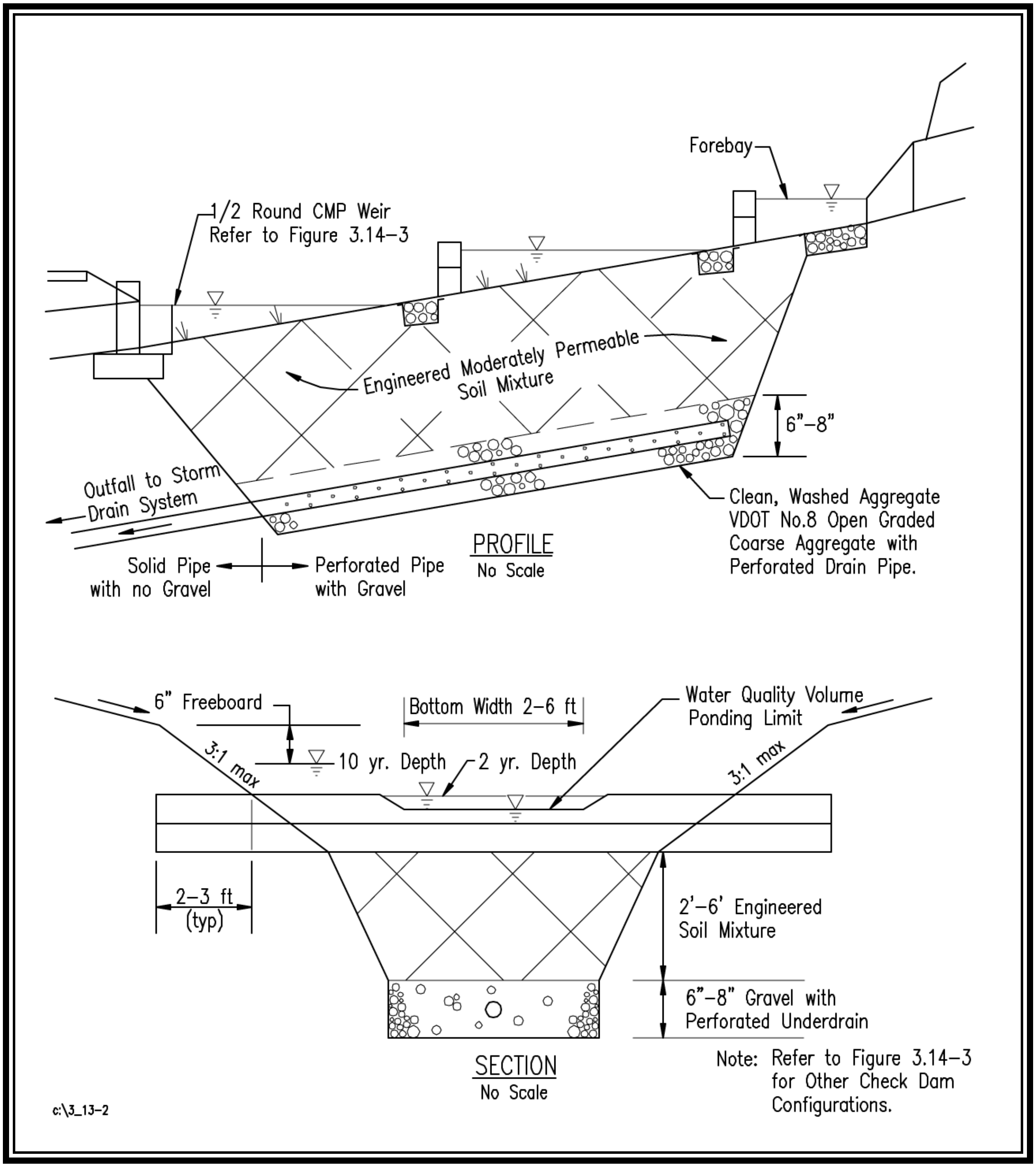


TABLE 3.13 - 1
Pollutant Removal Efficiency for Grassed Swales

Water Quality BMP	Target Phosphorus Removal Efficiency	Impervious Cover
Grassed Swale	15%	16 - 21%
Water Quality Swale	35%	16 - 37%

Channel Erosion Control

Grassed swales and water quality swales may also provide some benefits relative to channel erosion by reducing the peak rate of discharge from a drainage area. However, the holding capacity of a grassed swale designed for water quality purposes is limited.

Condition Where Practice Applies

Drainage Area

Grassed swales and water quality swales engineered for enhancing water quality cannot effectively convey large flows. Therefore, their contributing drainage areas must be kept small. The dimensions (length, width, and overall geometry) and slope of the swale, and its ability to convey the 10-year storm at a non-erosive velocity will set the size of the contributing drainage area.

Development Conditions

Grassed swales are commonly used instead of curb and gutter drainage systems in low- to moderate-density (16 to 21% impervious) single-family residential developments. Since grassed swales do not function well with high volumes or velocities of stormwater, they have limited application in highly urbanized or other highly impervious areas. However, swales may be appropriate for use in these areas if they are constructed in series or as pretreatment facilities for other BMPs.

Grassed swales are usually located within the right-of-way when used to receive runoff from subdivision or rural roadways. They may also be installed within drainage easements along the side or rear of residential lots. Grassed swales can be strategically located within the landscape to intercept runoff from small impervious surfaces (small parking lots, rooftops, etc.) as a component of a subdivision-wide or development-wide BMP strategy.

Water quality swales are appropriate for the same development conditions as those listed for grassed swales with the addition of higher densities of development (16 - 37% impervious) due to the increased pollutant removal capability.

Planning Considerations

Figure 3.13-1 pesents a grassed swale designed to hold small pockets of water behind each check dam. The water slowly drains through small openings in the chack dam and/or infiltrates into the ground. Slow channel velocities allow the vegetation to filter out sediments and other particulate pollutants from the runoff and increases the opportunity for infiltration and adsorption of soluble pollutants.

Figure 3.13-2 presents a water quality swale with an engineered soils media directly under the swale, with an underdrain. This design may be used in areas where the soils are not conducive to infiltration, or in developments where the swale is constructed beside a roadway using fill or compacted soils.

<u>Site Conditions</u>

The following items should be considered when selecting a grassed swale as a water quality BMP:

1. **Soils –** Grassed swales can be used with soils having moderate infiltration rates of 0.27 inches per hour (silt loam) or greater. Besides permeability, soils should support a good stand of vegetative cover with minimal fertilization.

   Water quality swales can be used in areas of unsuitable soil conditions for infiltration since the engineered soil mixture and underdrain system is used in place of the insitu soils.

2. **Topography –** The topography of the site should be relatively flat so that the swale can be constructed with a slope and cross-section that maintains low velocities and creates adequate storage behind the check dams.

3. **Depth to water table –** A shallow or seasonally-high groundwater table will inhibit the opportunity for infiltration. Therefore, the bottom of the swale should be at least 2 feet above the water table.

<u>Sediment Control</u>

Grassed swales may be used for conveyance of stormwater runoff during the construction phase of development. However, the swales should be maintained as required by the Virginia Erosion and Sediment Control Regulations and local program requirements. Before final stabilization, sediment must be removed from the swales and the soil surface prepared for final stabilization. Tilling of the swale bottom may be needed to open the surface pores and re-establish the soil's permeability.

Water quality swales should be constructed after a majority of the drainage area has been stabilized.

(Refer to **Min. Std. 3.11: Bioretention Facilities**).
This section presents minimum criteria and recommendations for the design of grassed swales used to enhance water quality. It is the designer's responsibility to decide which criteria are applicable to the particular swale being designed and to decide if any additional design elements are required. The designer must also provide for the long-term functioning of the facility by choosing appropriate structural materials.

Design Criteria

The design of a water quality grassed swale includes calculations for traditional swale parameters (flow rate, maximum permissible velocities, etc.) along with storage volume calculations for the water quality volume.

Hydrology

The hydrology of a grassed swale's contributing drainage area should be developed per **Chapter 4, Hydrologic Methods**.

Swale Geometry

A grassed swale should have a trapezoidal cross-section to spread flows across its flat bottom. Triangular or parabolic shaped sections will concentrate the runoff and should be avoided. The side slopes of the swale should be no steeper than 3H:1V to simplify maintenance and to help prevent erosion.

Bottom Width

The bottom width of the swale should be 2 feet minimum and 6 feet maximum in order to maintain sheet flow across the bottom and to avoid concentration of low flows. The actual design width of the swale is determined by the maximum desirable flow depth, as discussed below.

Flow Depth

The flow depth for a water quality grassed swale should be approximately the same as the height of the grass. An average grass height for most conditions is 4 inches. Therefore, the maximum flow depth for the water quality volume should be 4 inches (Center for Watershed Protection, 1996).

Flow Velocity

The maximum velocity of the water quality volume through the grassed swale should be no greater than 1.5 feet per second. The maximum design velocity of the larger storms should be kept low enough so as to avoid resuspension of deposited sediments. The 2-year storm recommended maximum design velocity is 4 feet per second and the 10-year storm recommended maximum design velocity is 7 feet per second.

Longitudinal Slope

The slope of the grassed swale should be as flat as possible, while maintaining positive drainage and uniform flow. The minimum constructable slope is between 0.75 and 1.0%. The maximum slope depends upon what is needed to maintain the desired flow velocities and to provide adequate storage for the water quality volume, while avoiding excessively deep water at the downstream end. Generally, a slope of between 1 and 3% is recommended. The slope should never exceed 5%.

Swale length

Swale length is dependent on the swale's geometry and the ability to provide the required storage for the water quality volume.

Swale Capacity

The capacity of the grassed swale is a combined function of the flow volume (the water quality volume) and the physical properties of the swale such as longitudinal slope and bottom width. By using the Manning equation or channel flow nomographs, the depth of flow and velocity for any given set of values can be obtained. The Manning's '*n*' value, or roughness coefficient, varies with the depth of flow and vegetative cover. An '*n*' value of 0.15 is appropriate for flow depths of up to 4 inches (equal to the grass height). The *n* value decreases to a minimum of 0.03 for grass swales at a depth of approximately 12 inches.

A grassed swale should have the capacity to convey the peak flows from the 10-year design storm without exceeding the maximum permissible velocities. (Note that a maximum velocity is specified for the 2-year and 10-year design storms to avoid resuspension of deposited sediments and other pollutants and to prevent scour of the channel bottom and side slopes.) The swale should pass the 10-year flow over the top of the check dams with 6 inches, minimum, of freeboard. As an alternative, a bypass structure may be engineered to divert flows from the larger storm events (runoff greater than the water quality volume) around the grassed swale. However, when the additional area and associated costs for a bypass structure and conveyance system are considered, it may be more economical to simply increase the bottom width of the grassed swale. It should then be designed to carry runoff from the 10-year frequency design storm at the required permissible velocity.

The longitudinal slope and the bottom width may be adjusted to achieve the maximum allowable velocity according to the Manning equation:

$$Q = \left[\frac{1.49}{n} r^{2/3} s^{1/2}\right] A$$

Equation 3.13-1
Manning Equation

Where:
Q = peak flow rate, cfs
n = Manning's roughness coefficient
r = hydraulic radius, ft. = A / wp
s = longitudinal slope of the channel
A = cross-sectional area of the channel, ft^2

The portion of the equation within the brackets represents the velocity of flow. **Equation 3.13-1** can be rewritten as:

$$Q = VA$$

Equation 3.13-2
Continuity Equation

Where:
Q = peak flow rate, cfs
V = flow velocity, ft/s = $\frac{1.49}{n} r^{2/3} s^{1/2}$
A = *cross-sectional area of the channel,* ft^2.

Additional guidance on the use of the Manning equation for the design of grassed swales is provided in the Virginia Erosion and Sediment Control Handbook (VESCH), 1992 edition.

Water Quality Volume

If a grassed swale is used as a conveyance channel, its purpose is to transport stormwater to the discharge point. However, the purpose of a water quality grassed swale is to slow the water as much as possible to encourage pollutant removal.

The use of check dams will create segments of the swale which will be inundated for a period of time. The required total storage volume behind the check dams is equal to the water quality volume for the contributing drainage area to that point. However, the maximum ponding depth behind the check dams should not exceed 18 inches. To insure that this practice does not create nuisance conditions, an analysis of the subsoil should be conducted to verify its permeability.

Underlying Soil Bed - Water Quality Swales

An underlying engineered soil bed and underdrain system may be utilized in areas where the soils are not permeable and the swale would remain full of water for extended periods of time (creating nuisance conditions). This soil bed should consist of a moderately permeable soil material with a high level of organic matter: 50% sand, 20% leaf mulch, 30% top soil. The soil bed should be 30 inches deep and should be accompanied by a perforated pipe and gravel underdrain system.

In residential developments with marginal soils, it may be appropriate to provide a soil bed and underdrain system in all grassed swales to avoid possible safety and nuisance concerns.

Check Dams

The use of check dams in a grassed swale should be per the following criteria:

1. **Height –** A maximum height of 18 inches is recommended, and the dam height should not exceed one-half the height of the swale bank.

2. **Spacing –** Spacing should be such that the slope of the swale and the height of the check dams combine to provide the required water quality volume behind the dams.

3. **Abutments –** Check dams should be anchored into the swale wall a minimum of 2 to 3 feet on each side.

4. **Toe Protection –** The check dam toe should be protected with riprap placed over a suitable geotextile fabric. The size (D_{50}) of the riprap should be based on the design flow in the swale. Class A1 Riprap is recommended.

5. **Overflow –** A notch should be placed in the top of the check dam to allow the 2-year peak discharge to pass without coming into contact with the check dam abutments, or the abutments may be protected with a non-erodible material. Six inches of freeboard should be provided between the 10-year overflow and the top of the swale.

6. **Riprap check dams –** Rip rap check dams should consist of a VDOT No. 1 Open-graded Coarse Aggregate core keyed into the ground a minimum of 6 inches, with a Class A1 riprap shell.

7. **Filter fabric –** Filter fabric is required under riprap and gabion check dams.

8. **Driveway culvert weirs –** Where a driveway culvert is encountered, a ½ round corrugated metal pipe weir bolted to the concrete driveway headwall may be utilized as a check dam, or a timber check dam placed at least one foot upstream of the culvert opening.

Outlets

Discharges from grassed swales must be conveyed at non-erosive velocities to either a stream or a stabilized channel to prevent scour at the outlet of the swale. Refer to VESCH, 1992 edition for design procedures and specifications regarding outlet stabilization.

Inflow Points

Swale inflow points should be protected with erosion controls as needed (e.g., riprap, flow spreaders, energy dissipators, sediment forebays, etc.).

Vegetation

A dense cover of water-tolerant, erosion-resistant grass or other vegetation must be established. Grasses used in swales should have the following characteristics:

- a deep root system to resist scouring,
- a high stem density, with well-branched top growth,
- tolerance to flooding,
- resistance to being flattened by runoff, and
- an ability to recover growth following inundation.

Recommended grasses include, but are not limited to, the following: Kentucky-31 tall fescue, reed canary grass, redtop, and rough-stalked blue grass. Note that these grasses can be mixed.

The selection of an appropriate vegetative lining for a grassed swale is based on several factors including climate, soils, and topography. For additional information, refer to STD. & SPEC. 3.32: Permanent Seeding in VESCH, 1992 edition.

Erosion control matting should be used to stabilize the soil before seed germination. This protects the swale from erosion during the germination process. In most cases, the use of sod is warranted to provide immediate stabilization on the swale bottom and/or side slopes. Refer to STD. & SPEC. 3.33: Sodding in VESCH, 1992 edition for additional information.

Construction Specifications

Overall, widely accepted construction standards and specifications, such as those developed by the USDA Soil Conservation Service or the U. S. Army Corps of Engineers, should be followed where applicable. Further guidance can be found in the SCS Engineering Field Manual. Specifications for the work should conform to the methods and procedures specified for earthwork, concrete, reinforcing steel, woodwork and masonry, as they apply to the site and the purpose of the structure. The specifications should also satisfy any requirements of the local government.

Sequence of Construction

The construction of grassed swales should be coordinated with the overall project construction schedule. The swale may be excavated during the rough grading phase of the project to permit use of the excavated material as fill in earthwork areas. Otherwise, grassed swales should not be constructed or placed into service until the entire contributing drainage area has been stabilized. Runoff from untreated, recently constructed areas may load the newly formed swale with a large volume of fine sediment. This could seriously impair the swale's natural infiltration ability.

The specifications for construction of a grassed swale should state the following:

- the earliest point in progress when storm drainage may be directed to the swale, and
- the means by which this delay in use will be accomplished.

Due to the wide variety of conditions encountered among projects, each project should be evaluated separately evaluated to decide how long to delay use of the swale.

Excavation

Initially, the swale should be excavated to within one foot of its final elevation. Excavation to the finished grade should be deferred until all disturbed areas in the watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. When final grading is completed, the swale bottom should be tilled with rotary tillers or disc harrows to provide a well-aerated, highly porous surface texture.

Vegetation

Establishing dense vegetative cover on the swale side slopes and floor is required. This cover will not only prevent erosion and sloughing, but will also provide a natural means to maintain relatively high infiltration rates.

Selection of suitable vegetative materials and application of required fertilizer and mulch should be per VESCH, 1992 edition.

Materials

1. **Check dams** – Check dams shall be constructed of a non-erosive material such as wood, gabions, riprap, or concrete. All check dams shall be underlaid by filter fabric per Std. & Spec 3.19: Rip Rap of VESCH, 1992 edition.

   a. *Wood* - pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.

   b. *Gabions* - hexagonal triple twist mesh with PVC coated galvanized steel wire. The maximum linear dimension of the mesh opening shall not exceed 4.5 inches. The area of the mesh opening shall not exceed 10 square inches.

   Stone or riprap for gabions shall be sized according to **Table 3.13-2**. It shall consist of field stone or rough unhewn quarry stone. The stone shall be hard and angular and of a quality that will not disintegrate with exposure to water or weathering. The specific gravity of the individual stones shall be at least 2.5.

   Recycled concrete may be used if it has a density of at least 150 pounds per cubic foot and does not have any exposed steel or reinforcing bars.

   c. *Riprap* - all riprap shall conform with VESCH Std. & Spec 3.19: Riprap, and VDOT Standards for open graded course aggregate.

   d. *Concrete* - All concrete shall conform with VDOT or SCS specifications.

2. **Underlying soil medium** – The underlying soils should consist of the following:

   a. *Soil* - USDA *ML*, *SM*, or *SC*.

   b. *Sand* - ASTM C-33 fine aggregate concrete sand; VDOT fine aggreagate, grading A or B.

3. **Pea Gravel** – Pea gravel should consist of washed ASTM M-43; VDOT No. 8 Open-graded Course Aggregate.

4. **Underdrain** – An underdrain system below the swale bottom shall consist of the following:

   a. *Gravel* - AASHTO #7, ASTM M-43, VDOT No. 3 Open-graded Course Aggregate.

   b. *PVC Pipe* - AASHTO M-278, 4-inch rigid schedule 40, perforations of 3/8-inch diameter at 6-inch centers, 4 holes per row.

   c. *Filter fabric* - shall be per specifications found in VESCH, 1992 edition.

TABLE 3.13 - 2
Stone or Riprap Sizes for Gabion Baskets

Basket Thickness		**Stone Size *(in.)***
(in.)	***(mm.)***	
6	150	3 - 5
9	225	4 - 7
12	300	4 - 7
18	460	4 - 7
36	910	4 - 12

Maintenance and Inspection Guidelines

Maintenance of grassed swales includes upkeep of the vegetative cover and preservation of the swale's hydraulic properties. Individual land owners can usually carry out the suggested maintenance procedures for the swale or the portion of the swale on their property. To ensure continued long term maintenance, all affected landowners should be made aware of their maintenance responsibilities, and maintenance agreements should be included in land titles.

The following maintenance and inspection guidelines are not intended to be all-inclusive. Specific swales may require other measures not discussed here. It is the engineer's responsibility for determining if any additional items are necessary.

Vegetation

A dense and vigorous grass cover should be maintained in a grassed swale. This will be simplified if the proper grass type is selected in the design. Periodic mowing is required to keep the swale operating properly. Grass should never be cut to a height less than 3 inches. Ideally, a grass stand of 6 inches is most effective. Stabilization and reseeding of bare spots should be performed, as needed.

Check Dams

Properly constructed check dams should require very little maintenance since they are made of non-erodible materials. Periodic removal of sediment accumulated behind the check dams should be performed, as needed.

Debris and Litter Removal

The accumulation of debris (including trash, grass clippings, etc.) in the swale can alter the hydraulics of the design and lead to additional maintenance costs. Debris can also alter the flow path along the swale bottom causing low flows to concentrate and result in erosion of the swale bottom. As with any BMP, frequent inspections by the land owner will help prevent small problems from becoming larger.

Sediment Removal

The sediment that accumulates within the swale should be manually removed and the vegetation reestablished. If accumulated sediment has clogged the surface pores of the swale, reducing or eliminating the infiltration capacity, then the surface should be tilled and restabilized. Drilling or punching small holes into the surface layer can be used instead of tilling, if desired.

FIGURE 3.13 - 3
Typical Check Dam Configurations

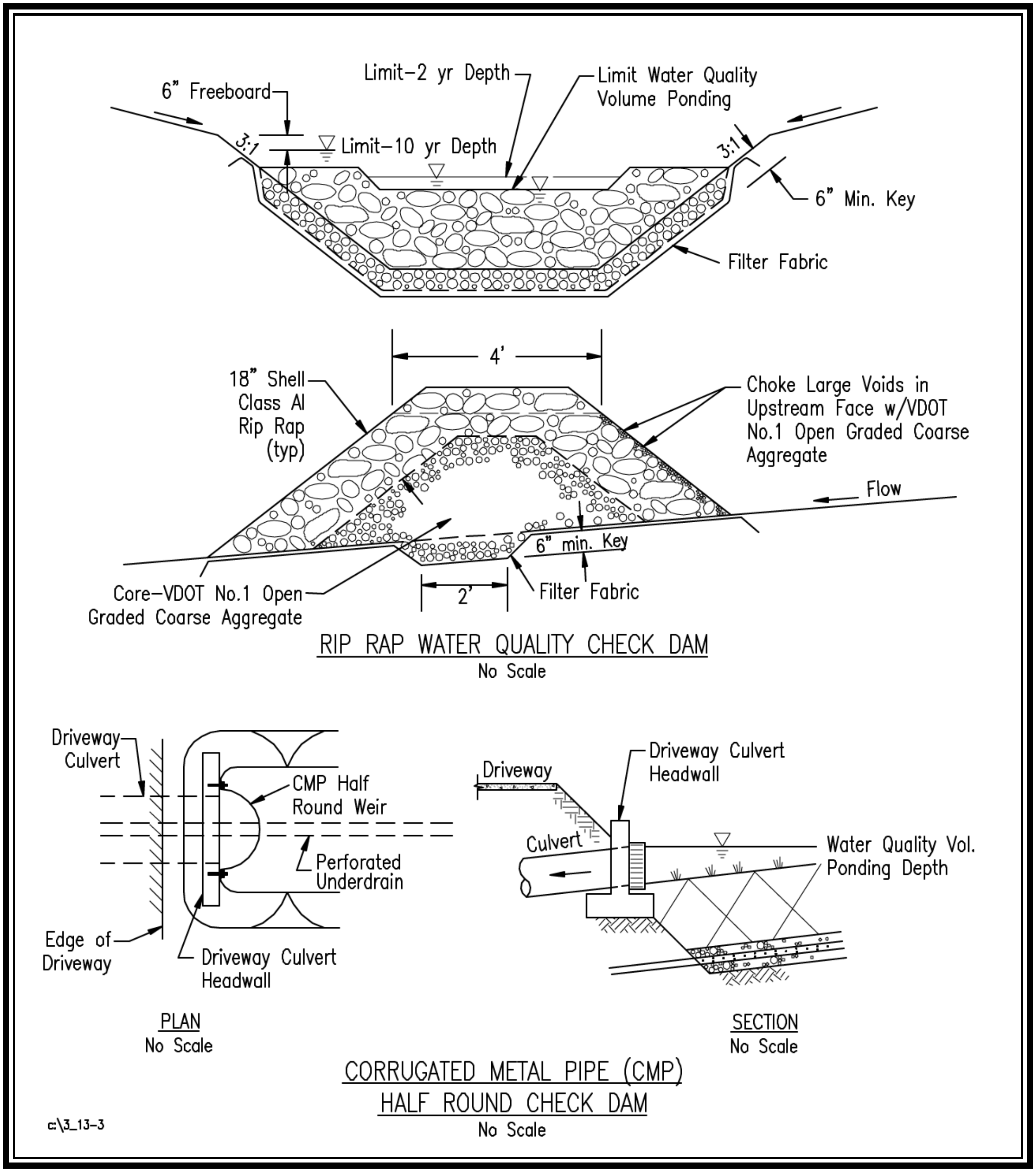
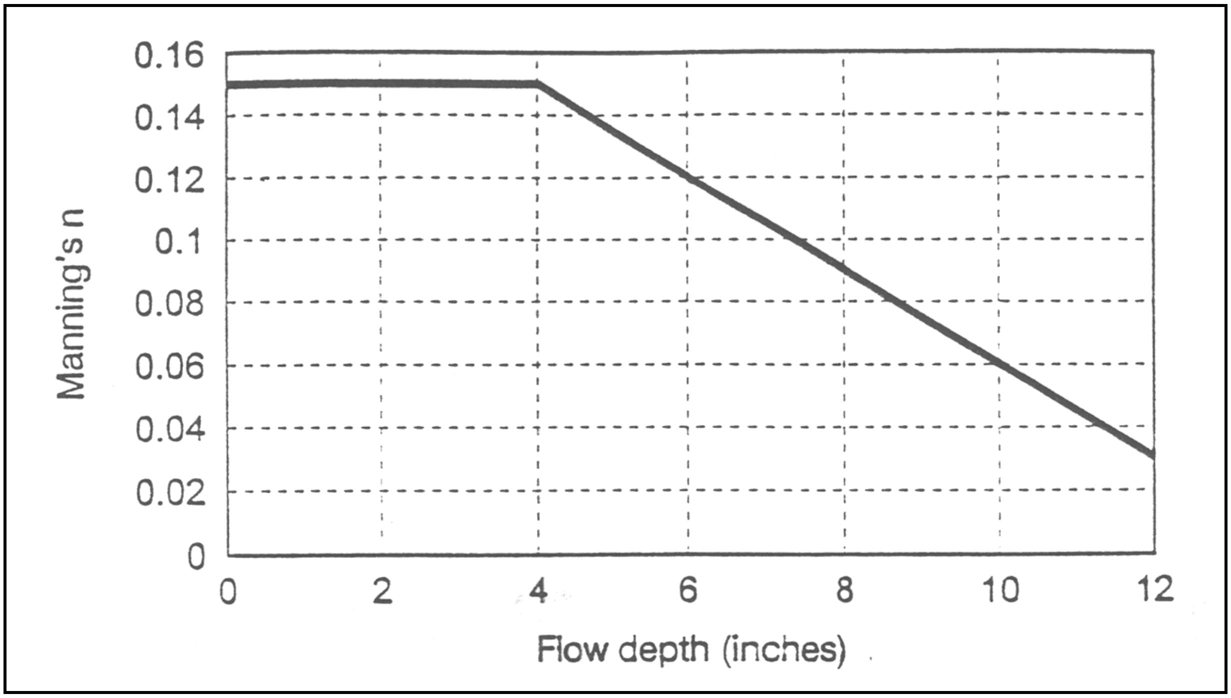


FIGURE 3.13 - 4
Manning's 'n' Values for Varying Depths of Flow



Design Procedures

The following design procedure represents a generic list of the steps typically required for the design of a *water quality grassed swale*.

1. Determine if the anticipated development conditions and drainage area are appropriate for a water quality grassed swale BMP.

2. Determine if the soils (permeability, bedrock, Karst, etc.) and topographic conditions (slopes, existing utilities, environmental restrictions) are appropriate for a grassed swale BMP.

3. Determine any additional stormwater management requirements (channel erosion, flooding) for the project.

4. Locate the grassed swale BMP(s) on the site.

5. Determine the hydrology and calculate the 2-year and 10-year peak discharges (**Chapter 4, Hydrologic Methods**), and the water quality volume for the contributing drainage area.

6. Approximate the geometry of the grassed swale and evaluate water quality parameters: water quality depth of flow (recommended maximum of 4 inches), and storage volume behind check dams (water quality volume). Adjust swale geometry and re-evaluate as needed.

7. Evaluate the grassed swale geometry for the the 2-year design storm peak discharge velocity (4 feet per second), and capacity (check dam overflow), and the 10-year design storm peak discharge velocity (7 feet per second) and capacity (6 inches of freeboard). (**Chapter 5, Engineering Calculations**). Adjust swale geometry and re-evaluate as needed.

8. Establish specifications for appropriate permenant vegetation on the bottom and side slopes of the grassed swale.

9. Establish specifications for sediment control.

10. Establish construction sequence and construction specifications.

11. Establish maintenance and inspection requirements.

REFERENCES

Arnold, J.A., ed., D.E. Line, S.W. Coffey, and J. Spooner. Stormwater Management Guidance Manual. Raleigh, North Carolina: North Carolina Cooperative Extension Service and North Carolina Division of Environmental Management, 1993.

Center for Watershed Protection. Design of Stormwater Filtering Systems. Silver Spring, Maryland: 1996

Chesapeake Bay Local Assistance Department. Chesapeake Bay Local Assistance Manual. Richmond, Virginia: 1989.

Galli, John. Analysis of Urban BMP Performance and Longevity. Washington, District of Columbia: Metropolitan Washington Council of Governments, 1992.

Hampton Roads Planning District Commission. Vegetative Practices Guide for Nonpoint Source Pollution Management. Chesapeake, Virginia: 1992.

Northern Virginia Planning District Commission and Engineers and Surveyors Institute. Northern Virginia BMP Handbook. Annandale, Virginia: 1992.

Schueler, T.R., P.A. Kumble, and M.A. Heraty. A Current Assessment of Urban Best Management Practices. Washington, District of Columbia: Metropolitan Washington Council of Governments 1992.

Virginia Department of Conservation and Recreation. Virginia Erosion and Sediment Control Handbook (VESCH). Richmond, Virginia: 1992.

Grass Swale. Note stone check dam in front of inlet creates shallow ponding area to encourage infiltration and settling.

Grass Swale through residential area. Note flat slope to encourage infiltration – ponding water gone within hours of runoff producing event.

Grassed Swale

DCR Chapter 3.13

Grass Swale with Check Dams. Note significant channel storage capacity created by check dams. Notched center allows safe overflow without scour around sides.

Grassed Swale